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DEVELOPMENTS IN FUEL CELL TECHNOLOGY

by

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TABLE OF CONTENTS

Page

INTRODUCTION 1

DESCRIPTION OF A FUEL CELL 1

REASONS FOR THE INTEREST IN FUEL CELLS 2

CHALLENGES 2

CURRENT DEVELOPMENTS; FUTURE PLANS 4

MICHIGAN'S PLACE IN THE HYDROGEN ECONOMY 6

CONCLUSION 7

INTRODUCTION

In his 2002 State of the State address, former Governor John Engler declared, "It is no longer a question of whether, but when, we will leave behind an economy powered by fossil fuels". Speaking specifically of fuel cell technology, he warned that State policymakers "ignore it at our peril". A short time later, the Governor announced his NextEnergy plan, an economic development program to construct a center for alternative energy research, development, commercialization, and manufacture through a variety of tax incentives. Related legislation was enacted in 2002.[1]

Subsequently, in his 2003 State of the Union address, President George W. Bush pledged $1.7 billion over the next five years for the development of technologies to produce, store, and distribute hydrogen as a viable source of fuel, and the FreedomCAR (Cooperative Automotive Research) initiative, to develop vehicles powered by fuel cells. Following the President's address, Michigan Governor Jennifer Granholm announced in her 2003 State of the State message that "not only will we build those cars in Michigan, our Automotive Technology Corridor will help develop the fuel cell technology those cars will run on."

This paper gives an overview of fuel cell technology, current developments, plans for the future, and Michigan's role in the transition to a hydrogen-based economy.

DESCRIPTION OF A FUEL CELL

The fuel cell can be described as a "chemical battery" that can convert a fuel directly into electricity without burning the fuel, as today's internal combustion engines do. While there are several types of fuel cells that function in a variety of applications, this paper generally refers to the proton exchange membrane (PEM) fuel cell.

A PEM fuel cell consists of an electrolyte, an anode, and a cathode, and produces electricity through a process known as reforming. Hydrogen is fed into the fuel cell at the anode, where the negatively charged electrons are stripped from the positively charged protons. The protons move through the electrolyte to the cathode. The electrons move through a wire connecting the anode to the cathode, creating an electric current. Oxygen from the air is fed into the cathode, where it combines with the electrons and protons to produce water vapor, the fuel cell's only emission. Since the amount of electricity produced by a fuel cell is very small, many applications would require a stack of hundreds of fuel cells.

Within the next decade, fuel cells are expected to grow into a $95 billion industry and power everything from laptop computers to large, commercial buildings. This paper focuses on two areas where fuel cells have the potential to be widely used: the electricity grid and transportation.

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[1] Public Act 593 of 2002 (Senate Bill 1316) created the Michigan Next Energy Authority to certify property and taxpayers for tax credits, and to promote the research, development, and manufacturing of alternative energy technology. Public Act 512 of 2002 (House Bill 6071) provided for the designation of an alternative energy renaissance zone. Public Act 531 (Senate Bill 1322) and Public Act 549 (House Bill 6074) created credits against the property tax and the single business tax, respectively. (For a detailed description of the legislation, please see the Senate Fiscal Agency's Enrolled Summary of Senate Bill 1316 (4-18-03), and the First Analysis of Senate Bill 1316 (7-31-02), which describes the enacted version of Senate Bill 1322 and House Bills 6071 and 6074.)

REASONS FOR THE INTEREST IN FUEL CELLS

Both environmental and political factors contribute to increased interest in the search for alternative energy sources. The United States uses 25% of the world's oil, yet has only 3% of the world's oil reserves. This country consumes 20 million barrels of oil every day, 58% of that imported. Unless new fuel sources are found or consumer behavior changes drastically, America will be importing 65% of its oil by 2020. Already an estimated $1 billion per week from the U.S. economy goes to foreign oil. Policymakers, industry players, and consumers also cite instability in the Middle East as a significant reason to focus on other sources of energy to power automobiles, heat homes, and keep businesses running.

In addition to geopolitical conflict, increasing demand and decreasing supply exacerbate concerns about oil. Americans purchase 17 million new cars, trucks, and SUVs every year, a number that probably will continue to rise. Scientists predict that the overall global oil supply is nearing its peak, and that oil production will drop off worldwide over the next 10 to 20 years. Future scarcity of oil and other carbon-based fuels like petroleum and natural gas place enormous pressure on automakers to develop new technologies, on individuals to change their consumption habits, and on societies to adapt.

From an environmental perspective, this country's energy consumption contributes to pollution and global warming, prompting calls to find a cleaner fuel. Automobiles in the United States pump 1.5 billion tons of carbon dioxide equivalent per year into the air, and in the Great Lakes region, transportation and utilities account for 53% of heat-trapping gases.[2] Various "greenhouse" gases and other pollutants can lead to assorted health problems, and, many people believe, global climate change.

America's electricity grid today consists of centralized power generation, in which electricity is produced at a power plant and then transmitted over miles of lines to the point of need. Proponents see a huge potential for fuel cells in distributed generation (DG), a system in which small electric generators function close to where the energy is used. The U.S. Department of Energy is advocating that 20% of all new electric generation installed in 2010 be DG. Under such a grid, homes and businesses would produce their own electricity with a fuel cell device. Evidently, small, self-contained electric generators would be vastly more efficient than today's large power grid, which is only about 30% efficient. Some involved in the industry predict that, if a DG unit were to produce more electricity than was necessary, the excess could flow back into the grid and the owner could be compensated.

CHALLENGES

While there is excitement over the benefits of fuel cells, a significant amount of skepticism exists and some even call the fuel cell a "Trojan horse". Commercial development is stalled by problems that existing technology cannot solve, and some argue that spending millions of dollars on fuel cell development is not justifiable in light of the benefits foreseeable in the near future.

The largest barrier to the development and proliferation of fuel cells is the absence of an energy source. Though hydrogen is the most abundant element on the planet, it usually is not in a usable form. It is generally locked up in hydrocarbons and must be extracted through combustion or

[2] Tarek El-Tablawy, "Two-year Great Lakes Study Calls for Lower Emissions", *The Detroit News*, April 8, 2003.

separated from water in nuclear reactors. Both processes negate the environmental benefits that using hydrogen would produce. Researchers have not yet figured out how to extract hydrogen using renewable resources, such as wind or solar power, on a cost-effective basis.

One of the greatest uncertainties when it comes to hydrogen-powered vehicles is infrastructure. Consumers will not buy fuel cell vehicles if refueling them is inconvenient, and the industry will not want to invest in constructing hydrogen fuel stations if the popularity of the vehicles is questionable.

Another problem is the question of storage. In liquid form, hydrogen must be kept at -253 degrees Celsius. If hydrogen is gaseous, its storage tank must be wrapped in a carbon fiber and be able to withstand pressures of 10,000 pounds per square inch. Furthermore, hydrogen has a reputation for volatility, and many question its safety. According to industry representatives, however, hydrogen, when handled properly, is no more dangerous than any other fuel. Companies working to develop a practical storage tank subject the tanks to numerous safety tests, including exposing them to fire, subjecting them to extreme temperatures, and even shooting them. The DOE has asked Congress nearly to triple funding for research and development of hydrogen storage tanks, from $11 million in 2003 to $30 million in 2004.

Perhaps one of the largest barriers to the commercialization of fuel cell cars is the cost. One fuel cell of the type that would be used in automobiles now costs $200,000. To produce enough energy to power a car, multiple fuel cells would be needed to form a fuel cell stack. One reason for this is that many parts of a fuel cell currently must be made by hand. Until manufacturers can figure out how to mass-produce them, the cost will remain astronomical. Additionally, fuel cell vehicles require much more platinum than a conventional vehicle does. Less than a half-ounce of platinum is used in a typical gasoline-powered car's catalytic converter. A vehicle powered by a fuel cell stack would require about three ounces of platinum, which currently costs $680 per ounce. The proton exchange membrane also is very expensive, at $100 per kilowatt of energy produced.[3] Because of the large amounts of platinum needed and the intricate manufacturing process, a fuel cell engine now costs approximately 10 times more than a typical internal combustion engine. According to a General Motors (GM) fuel cell expert, the gas-powered engine on a $20,000 vehicle costs about $3,000. A fuel cell engine for the same car costs $30,000.

In addition to infrastructure, storage, and cost problems, many environmentalists question both the motivation for and the worth of fuel cell investment. Some claim that automakers are using fuel cell research as an excuse not to improve fuel efficiency and reduce emissions for trucks and SUVs. They say that more should be done to improve the conventional vehicles consumers already have, and point out that, while President Bush has emphasized the environmental benefits of fuel cells, he recently announced sizeable tax incentives for businesses that purchase SUVs. Despite $1 billion in taxpayer funding, President Bill Clinton's Program for a New Generation of Vehicles, predecessor to the FreedomCAR program, failed to produce significant developments in alternative energy or zero-emissions cars.

According to some environmentalists, researchers, and consumers, automakers are ignoring other promising avenues that could provide monetary and environmental benefits much sooner than fuel cells will. One of these is the use of diesel fuel, which earned a bad reputation in the past for the unpleasant odor and heavy pollution it produced. Diesel today is vastly improved in its emissions and is extremely popular in Europe, and consumer diesel vehicles get 40% to 70% better gas mileage than gasoline-powered vehicles.[4]

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[3] Jeff Bennet, "Focus on Fuel Cells: Experts Meet Today to Discuss Cutting Costs", *The Detroit Free Press*, March 5, 2003.

[4] "America is Missing Diesel's Fuel-Saving Potential", *The Detroit News*, March 4, 2003.

Another technology that United States auto companies might be neglecting is the gasoline-electric hybrid vehicle, which several Japanese companies have introduced with slow but significant market penetration. Some people warn that it might be unwise to place great faith in the future value of fuel cells at the expense of the hybrid car, which the Center for Automotive Research has called "a critical enabler for automotive fuel cell application".[5] Some argue that the hybrid is essential to changing the mindset of consumers, who might be reluctant to adopt alternatives to conventional vehicles.

CURRENT DEVELOPMENTS; FUTURE PLANS

In March 2003, the U.S. Department of Energy and the European Union announced a cooperative effort to bring commercially viable hydrogen-powered cars and electricity generated from fuel cells to the general public within the next 20 years. The Bush administration plans to focus on coal, of which the United States has an abundant supply, as the main source of hydrogen, and is supporting a project to find a way to extract the hydrogen without generating more carbon dioxide in the atmosphere.[6]

Some auto companies plan to produce affordable, commercially viable hydrogen-powered cars by the end of the decade. General Motors predicts that it will sell 1 million hydrogen vehicles by 2015. Some in the industry envision a future in which a fuel cell car, while parked, would produce energy that could then be sold to the grid for the owner's economic benefit.

Several researchers predict that the time when fuel cell vehicles will be commonplace is still far off, and a hydrogen-based economy even further. They say that the beginnings of a hydrogen-based economy might appear in the next 50 to 100 years, once society learns to use renewable resources, such as wind and solar energy, to obtain hydrogen in a cost-efficient manner. A representative of Plug Power Fuel Cell Systems, an unregulated subsidiary of DTE Energy, hypothesizes that a hydrogen-based DG system will not entirely replace the current energy grid any time soon, if ever, and the two systems most likely will co-exist for a while.

While the days of a hydrogen-based economy might remain distant, in the next few years there probably will be an increase of small electronic devices, such as laptop computers and cellphones, powered by fuel cells. This market should not be plagued by the problem of infrastructure as the transportation sector is, and these smaller fuel cells are likely to appeal to customers because of their convenience. A lithium ion battery can provide one watt of power for about 150 hours, while a fuel cell powered by hydrogen extracted from methanol could provide one watt for 6,000 hours.[7]

DaimlerChrysler AG launched its prototype of what is said to be the first viable fuel cell car, NECAR IV, in 1999. Ford currently has five demonstration and marketing vehicles, along with 10 road and test lab vehicles. The company plans to have a low-volume production program by 2004 with a target market in California, where Ford would work in various partnerships to facilitate construction of a refueling infrastructure. Ford also is working with Dynetek to provide a mobile hydrogen fueling station, which is a lightweight trailer that can be easily towed behind a pick-up truck to

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[5] Brett C. Smith, The Center for Automotive Research at Erim, Inc., "Positioning the State of Michigan as a Leading Candidate for Fuel Cell and Alternative Powertrain Manufacturing", August 2001.

[6] Neela Banerjee, "U.S. and Europe in Fuel Cell Pact", *The New York Times*, March 7, 2003.

[7] Barnaby J. Feder, "For Far Smaller Fuel Cells, a Far Shorter Wait", *The New York Times*, March 16, 2003.

deliver hydrogen to remote customers. The company expects full commercialization of its fuel cell vehicle by 2012.

In both its fuel source and appearance, GM's $5 million fuel cell concept car marks a dramatic departure from conventional automobiles. The Hy-wire has no pedals or steering wheel and instead is directed by a set of hand controls, similar to motorcycle handles. The body snaps on to an 11-inch thick, skateboard-like chassis, allowing for frequent body-swapping as styles change. Reportedly, FedEx plans to make deliveries in Japan using GM's HydroGen3 fuel cell car starting this June.[8]

In March 2003, DaimlerChrysler AG announced plans to lease up to 10 fuel cell vehicles in Japan beginning in the second half of 2003. The company is currently in discussions with Mitsubishi to provide support for the project in the form of maintenance. Toyota and Honda already have leased their versions of the fuel cell car to the Japanese government and several U.S. customers in California.[9] Honda has developed a fuel cell model car with a range double that of the commercially unsuccessful electric car, and planned to lease five of them to the City of Los Angeles by June 2003.

Ford, General Motors, and DaimlerChrysler AG also are involved in a partnership with the Army's National Automotive Center to modify existing trucks for military applications. Under the $14-billion Combatt (commercially based tactical truck) program, the GM Combatt hybrid truck has a five-kilowatt fuel cell that, due to the relatively small amount of heat generated, renders the vehicle largely undetectable when parked. The fuel cell provides enough energy to power the truck's surveillance equipment for up to five hours.[10]

In April 2003, Royal Dutch Shell, DaimlerChrysler AG, Icelandic New Energy, and Norsk Hydro opened a hydrogen filling station in Reykjavik, partially financed by the European Union.[11] General Motors and Shell recently announced a partnership in which GM will provide six fuel cell minivans in the Washington, D.C., area for use by lawmakers and Shell will modify an existing gas station to provide fuel for a public hydrogen station, which Shell hopes to open by October 2003.[12] Four hydrogen fueling stations have been opened in California as part of Toyota's program leasing six fuel-cell hybrid vehicles to the University of California-Irvine and the University of California-Davis.[13] Also, industry representatives say that fleet operations, such as city bus systems, provide a good

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[8] Lindsay Whipp, "DaimlerChrysler Plans to Lease Fuel-cell Car in Japan", *The Detroit News*, March 11, 2003.

[9] Lindsay Whipp, "DaimlerChrysler Plans to Lease Fuel-cell Car in Japan", *The Detroit News*, March 11, 2003.

[10] Sue Mead, "In Times of War, Detroit Enlists; On Horizon, Military Sees High-Technology Trucks", *The New York Times*, March 30, 2003.

[11] Richard Middleton, "Iceland Opens Hydrogen-Filling Station", *The Washington Post*, April 24, 2003.

[12] John Tierney, "Gas Station to Pump Hydrogen", *The New York Times*, March 5, 2003.

[13] John O'Dell, "Toyota, Honda Deliver 1st U.S. Fuel Cell Vehicles", *The Los Angeles Times*, December 3, 2002.

starting point for the transition to hydrogen-fueled automobiles because they have their own centralized fueling stations, which would mitigate the complications caused by lack of infrastructure.

In an extension of diesel fuel use, some consumers are experimenting with vehicles powered by various biofuels. For example, students in the Fowlerville, Michigan, school district are transported by buses that run on a blend of 80% petroleum diesel and 20% soybean oil. This particular mixture, called B20 fuel, improves engine lubrication and produces in its emissions less carbon monoxide, cancer-causing compounds, and unburned hydrocarbon emissions than regular petroleum diesel produces.[14] Legislation enacted in April, Public Act 5 of 2003, offers a property tax abatement for facilities that produce biodiesel in plant rehabilitation and industrial development districts.

MICHIGAN'S PLACE IN THE HYDROGEN ECONOMY

As home of the auto industry, Michigan is in a unique position to be a leader in fuel cell technology research and development. Construction on the 40,000-square foot NextEnergy facility in Wayne State University's Research and Technology Park is expected to be completed in the summer of 2004. The program was recently awarded $2 million in Federal funding.[15] Currently, almost 100 companies, including 38 in Oakland County, are involved in the NextEnergy initiative.

The State's universities also expect to participate in fuel cell development, and several already have made substantial investments. The engineering school, Kettering University, is investing $35 million in a new mechanical engineering and chemistry building with two fuel cell testing labs and a center powered by a stationary fuel cell. An adjacent research park also has been proposed, and university officials are hoping the new facilities will propel Michigan to the forefront of fuel cell research and development, through education, standards and codes, demonstrations, alliances, and public awareness.

The Muskegon City Council, in collaboration with the Michigan Economic Development Corporation and Grand Valley State University, has designated a part of downtown Muskegon as a Smart Zone, which is to have a focus on fuel cells. The redeveloped brownfield has 25,000 square feet and 16 lots open for development, and will be anchored by the Michigan Alternative and Renewable Energy Center, which will feature a stationary fuel cell, heat recovery system, and solar roof. Several Michigan-based companies have expressed an interest in investing in the project and, to date, $7 million has been secured.

While Michigan, as the home of the auto industry, might seem the natural location for fuel cell development, it does face competition from other states. These include Ohio, whose Third Frontier Project will dedicate $1.6 billion over 10 years to high-tech research, with $100 million earmarked for fuel cell development.[16]

Some involved in the industry have pointed out that, while Michigan is home to thousands of workers skilled in all aspects of automobile manufacturing, many of these skills do not easily

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[14] Linda Theil, "Soybean Oil Mixture Fuels Fowlerville School Buses", *The Detroit News*, February 28, 2003.

[15] Charles E. Ramirez, "Fuel Cell Project to get $2 Million", *The Detroit News*, March 7, 2003.

[16] Alejandro Bodipo-Memba, "Michigan vs. Ohio: States Compete to be the Fuel Cell Capital", *The Detroit Free Press*, June 26, 2002.

translate to the manufacture of fuel cells. Some have said that the switch to fuel cells could jeopardize nearly 200,000 jobs and result in a $10 billion loss to a State economy based on the internal combustion engine. A 2001 report by the Center for Automotive Research (CAR) asserts that Michigan's auto industry will have to use a completely new powertrain production-manufacturing paradigm if Michigan is to remain a leader in fuel cell vehicle production.

In its report, CAR advised that the State should not place all of its resources behind one technology or company, and a researcher from Kettering University suggested that rather than focusing just on Detroit, policy-makers should take advantage of university research, industry initiatives, and partnerships throughout the State. The Center recommended that the State consider the following, if it wishes to attract fuel cell and other alternative energy development:

- Creating a Michigan Advanced Powertrain Technology Alliance.
- Investigating the feasibility of creating a power electronics "Center of Excellence".
- Establishing a Michigan Hydrogen Infrastructure Working Group.
- Promoting demonstration and testing of prototype fuel cell vehicles and supporting commercialization of fuel cells for advanced vehicles and stationary applications.
- Conducting an economic study to determine the most appropriate financial incentives for development of commercialization of fuel cell and other advanced technology vehicles.

CONCLUSION

Representatives of the automotive and technology industries and several members of academia have made suggestions for policy-makers. Those in the industry say that increasing investment in fuel cell research and offering industry incentives, such as tax credits, low-interest loans, and bond financing, are critical to advancing fuel cells to a level of widespread commercial viability. It also has been suggested that governmental units at all levels can lead by example, by becoming early adopters of alternative energy sources as they are developed. A Plug Power representative cited numerous facilities throughout the world where fuel cells are being used to provide electricity, including various town and city halls, a Denver fire station, and several Army and Navy facilities. Los Angeles recently opened a small fuel cell power plant next to the Department of Water and Power's headquarters. The power plant is capable of providing enough electricity for 250 homes, and, while the electricity costs five times more than traditional power, the cost is expected to come down as the technology improves.[17]

Some researchers and corporate spokespersons have emphasized the importance of collaboration in developing viable hydrogen-based applications. While this would surely involve cooperation between private companies, it also might necessitate regional coordination over several states.

With respect to distributed generation, a supportive regulatory environment will be critical. The ease and affordability of connecting to the electricity grid, the fairness of standby and exit fees to compensate traditional utilities for revenue loss, and the standardization of certification of fuel cell devices are significant issues that policy-makers will have to address if DG is to become more widespread.

[17] Patrick McGreevy, "L.A. Plugs in Tiny, Nonpolluting Power Plant", *The Los Angeles Times*, March 15, 2003.

Further, some have said that it is impractical and unaffordable to build an infrastructure based on hydrogen all at once. They argue that it should be built as needed, existing along with conventional infrastructures to facilitate the evolution of a hydrogen-based economy. Secretary of Energy Spencer Abraham has emphasized the government's effort to ensure that fuel cell vehicles, the hydrogen delivery network, and filling stations are ready at the same time.[18]

Whether hydrogen will become a practical source of fuel within the next decade or within the next 100 years is uncertain. Fuel cell technology, however, provides Michigan-based companies, from small, local firms to globally recognized corporations, with unique opportunities to solve the challenges associated with its development.

[18] Jamie Butters, "Call for Fuel Cells Comes Home", *The Detroit Free Press*, February 8, 2003.